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Published:
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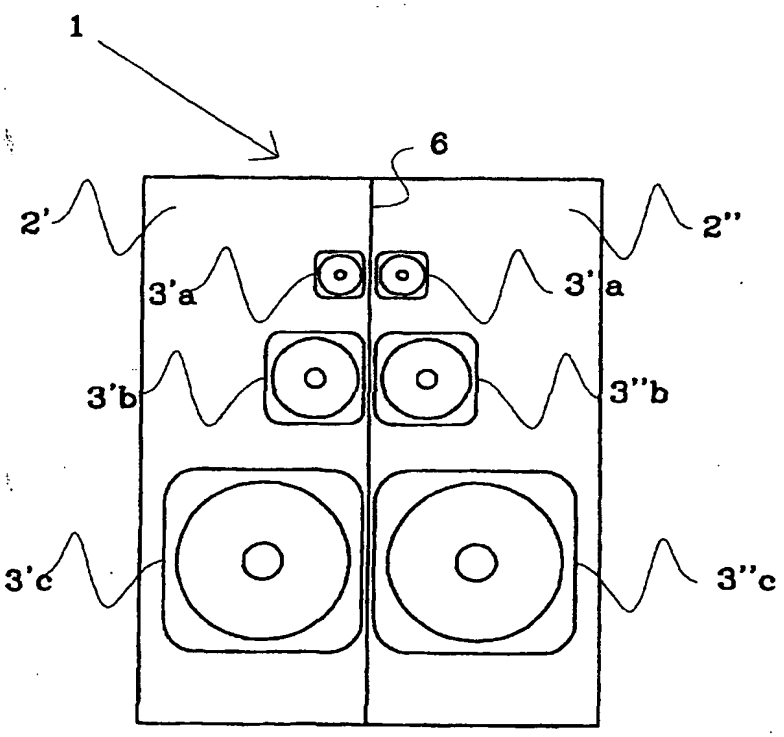
For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: A METHOD OF PROCESSING AND REPRODUCING AN AUDIO STEREO SIGNAL, AND AN AUDIO STEREO SIGNAL REPRODUCTION SYSTEM



(57) Abstract: A method of processing and reproducing an input audio stereo signal in an audio signal processing system comprises the steps of (1) splitting a side signal into a first and a second intermediate signal, where the first intermediate signal is equal to the side signal and the second intermediate signal is equal to the first intermediate signal phase shifted 180°, (2) attenuating the mid signal by a factor a which compensates for imperfections in the balance between the mid and side signals appearing in the audio reproduction stage, (3) adding the attenuated mid signal to both of the first and second intermediate signals, so as to form the output audio stereo signal, and (4) directing the output stereo signal to an audio stereo signal reproduction system, comprising a pair of loudspeaker units located in close proximity to each other. A suitable audio stereo signal reproduction system comprises a pair of loudspeaker units (2', 2'') having a common baffle and each pair of loudspeaker units (2', 2'') is positionable as a unitary assembly in close proximity to each other.

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A METHOD OF PROCESSING AND REPRODUCING AN AUDIO STEREO SIGNAL, AND AN AUDIO STEREO SIGNAL REPRODUCTION SYSTEM

FIELD OF THE INVENTION

The present invention relates in general to a method of processing and reproducing an audio stereo signal and to a corresponding audio stereo signal reproduction system. More particularly, the present invention relates to an audio stereo signal reproduction system with a very narrow distance between right and left side loudspeakers, and to a method of processing an audio stereo signal for retaining the apparent stereo width in the perceived sound picture emitted from such a reproduction system.

BACKGROUND OF THE INVENTION

A large number of methods and systems exist intended for faithful reproduction of the sound experienced by a listener at the recording position. The only one of these that is able to truly reproduce the stereo effect, i.e. the impression of the different sound sources originating from different spatial positions, is using stereo headphones. This method is however not suitable for reproduction of stereo sound to an audience consisting of more than one listener. To overcome this drawback, audio stereo reproduction systems comprising two, or more, loudspeakers are used for reproducing stereo sound to an audience. Most of these systems are based on a pair of widely spaced loudspeakers, and true reproduction of the stereo effect, both in terms of relative intensity between the sound perceived by the listeners' two ears and the time difference between these, can be perceived only at a single position in relation to the loudspeakers. This implies that only one listener in an audience can experience a truly correct stereo effect. All other members of the audience will therefore experience a distorted stereo effect. Different ways to widen

the area over which the perceived stereo impression is nearly correct have been attempted, with varying degrees of success.

Physically separating the two loudspeakers a distance large enough for enabling reproduction of the stereo impression to at least one listener is generally impractical, and in certain cases impossible. Examples of such cases is single unit stereo radio or CD players with integral loudspeakers, or reproduction of stereo sound to several listeners in cars or small rooms. Artificially adjusting the relative intensities of the side and the mid signals, to increase the perceived stereo width might improve the impression of stereo, but will also distort the sound picture. Other methods of improving the perceived stereo effect from narrowly separated loudspeakers have also been suggested, but have proven to give limited effect.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a method for processing an audio stereo signal, such that it can be reproduced with a high degree of fidelity in the perceived stereo effect over a larger area than possible with previous methods.

It is another object of the present invention to provide a method for processing an audio stereo signal, such that it can be reproduced with a high degree of fidelity in the perceived stereo effect, using a pair of loudspeakers being situated in immediate vicinity of each other.

According to the present invention, the method comprises the steps of splitting the side signal into a first and a second intermediate signal, where said first intermediate signal is equal to the side signal and said second intermediate signal

is equal to said first intermediate signal phase shifted 180° and attenuating the mid signal by a factor α. Then the attenuated mid signal is added to both of said first and second intermediate signals, so as to form said output audio stereo signal. Finally, the output stereo signal is directed to an audio stereo signal reproduction system, comprising a pair of loudspeaker units located in close proximity to each other.

It is yet another object of the present invention to provide a loudspeaker system, comprising identical pairs of loudspeaker elements, suited for reproducing an audio stereo signal processed according to the presented method.

According to the present invention, the system comprises a pair of loudspeaker units being acoustically isolated from each other. The loudspeaker elements of said pair of loudspeaker units are positionable as a unitary assembly in close proximity to each other, and each loudspeaker element of each pair of corresponding, identical loudspeaker elements of the two units is mounted at essentially the same height. The loudspeaker elements of at least one of said pairs are mounted in immediate vicinity of each other.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram illustrating the processing method according to the invention;

Fig. 2 is a front view of an embodiment of a loudspeaker system; and

Fig. 3 is a partial cross sectional top view of the loudspeaker system shown in Fig. 2.

DESCRIPTION OF A PREFERRED EMBODIMENT

Fig. 1 illustrates the method of processing an audio stereo signal according to the present invention. The audio stereo signal comprises a mid signal M, and a side signal S, corresponding to the difference between the left and right stereo signals, and the sum of the left and right stereo signals, respectively. Obviously, the method could equivalently be described in terms of left and right side components of an audio stereo signal, but as a matter of convenience, the method is described using the M and S picture only. According to the method, the S signal is split into two parts, one of which is a first intermediate signal S′ equal to S, and the other of which is a second intermediate signal S′′, equal to S′ but phase shifted 180°, or inverted, relative to S (and S′).

The mid signal M is attenuated a factor α, which, assuming the recording system as well as previous and subsequent stereo signal processing and stereo reproducing systems are optimal, would be typically -3 dB. In a general case, however, it is adapted to optimise the stereo effect perceived by the listener, and is allowed to vary in an interval from -1.5 dB to -10 dB. The attenuated mid signal is then added to the first and second intermediate signals S′ and S′′, respectively, and the resulting pair of signals are fed to an audio stereo signal reproduction system. Reproducing the resulting signals by an ordinary audio reproduction system with widely separated loudspeaker elements does however not give a satisfactory result, and only by using the audio stereo signal reproduction system according to the present invention, a stereo effect is reproduced with fidelity.

As the human ear does not appreciate any directionality, i.e. no stereo effect, from sound waves with very long wavelength, the signal processing according to the present invention is meaningless for low frequency sound. Therefore, it might be more cost effective to reproduce the bass using one separate loudspeaker unit only, and not to use the method of processing according to the present invention for that part of the frequency spectrum.

Fig. 2 shows a preferred embodiment of the audio stereo signal reproduction system according to the present invention. The sound reproduction system 1 comprises two sound reproducing units 2' and 2'', each of which comprises one or several, in this case three, loudspeaker elements 3'a, 3'b, 3'c and 3''a, 3''b, 3''c. As shown, the sound reproduction system 1 could include one common baffle 5 with a barrier 6 between the two sound reproducing units 2' and 2'', acoustically isolating the resonator volumes of the two units from each other. The term acoustical isolation does here imply that no, or little, sound is transferred from one resonator volume to the other. Alternatively it could consist of two separate units, placed in immediate vicinity of each other, or even being attached to each other. In each instance, each pair of corresponding loudspeaker elements in each of the sound reproducing units should be positioned symmetrically with respect to the separating plane, which in the illustrated embodiment would be defined by the barrier 6, in order to achieve a uniform sound pattern being emitted by each pair of loudspeaker elements 3'a, 3''a, etc. In addition, each loudspeaker element 3'a, 3''a etc. of each pair should be positioned as close to the other as practically possible in order to get minimal coloration caused by lobing in the resultant emitted sound pattern due to interference between the loudspeaker elements.

This is achieved when the distance between the loudspeaker elements is smaller than one quarter of the wavelength of the sound being emitted. Achieving this implies that higher frequency loudspeaker elements should be put closer to each other than lower frequency loudspeaker elements.

For sound reproduction systems employing low (first or second) order filters for separating out the parts of the frequency intervals to be reproduced by the mid and high frequency loudspeaker elements, respectively, a comparatively large frequency interval remains which is partially reproduced by both the mid and high frequency loudspeaker elements. This effect will distort the fidelity of the stereo reproduction, and in such a case, it may me preferred to position the mid and high frequency loudspeaker elements in line with each other horizontally. To compensate for the high frequency loudspeaker elements in this case not being positioned as close to each other as possible, the mid signal attenuation factor α is preferably frequency dependent, $\alpha(f)$, where f is the frequency.

In fig. 3 a plate element 4 positioned between the sound reproducing units 2' and 2'' is more clearly illustrated. This optional element serves the purpose of enhancing the perceived stereo effect for the high frequency part of the audio spectrum. The plate element 4 is positioned symmetrically with respect to the sound reproducing units and extends essentially orthogonally from the front surface 5 of the sound reproducing units. Its shape and extension from the front surface are adapted to the acoustical properties of the environment, in which the audio stereo signal reproduction system is to be used, and by the properties of the loudspeaker elements 3. The acoustical properties of the plate element should be neutral

and it should preferably have an absorption factor of 0.5 or less at 20 kHz. It may be retractable and extendable in order to optimise the performance of the system when the acoustical properties of the surroundings are varying.

Inasmuch as the present invention is subject to variations, modifications and changes in detail, some of which have been stated herein, it is intended that all matter described throughout this entire specification or shown in the accompanying drawings be interpreted as illustrative and not in a limiting sense.

CLAIMS

1. A method of processing and reproducing an input audio stereo signal in an audio signal processing system so as to form a processed output audio stereo signal, the input audio stereo signal consisting of at least a part of the frequency range of a mid signal (M) and a side signal (S), comprising the steps of:

- splitting the side signal (S) into a first (S') and a second (S'') intermediate signal, where said first intermediate signal (S') is equal to the side signal (S) and said second intermediate signal (S'') is equal to said first intermediate signal (S') phase shifted 180°,

- attenuating the mid signal (M) by a factor α which compensates for imperfections in the balance between the mid (M) and side signals (S) appearing in the audio reproduction stage,

- adding the attenuated mid signal to both of said first and second intermediate signals (S', S''), so as to form said output audio stereo signal, and

- directing said output stereo signal to an audio stereo signal reproduction system, comprising a pair of loudspeaker units located in close proximity to each other.

2. The method according to claim 1, c h a r a c t e r - i z e d i n that the attenuation factor α is in the range - 1.5 dB to -10 dB.

3. The method according to claim 1 or 2, c h a r a c t e r i z e d i n that the attenuation factor α is in the range -2.5 dB to -6 dB.

4. The method according to any of claims 1 - 3, c h a r a c t e r i z e d i n that the attenuation factor α is frequency dependent in the mid frequency range.

5. The method according to any one of claims 1 - 4, c h a r a c t e r i z e d i n that an upper part of the frequency range of said input audio stereo signal is processed in said audio signal processing system, so as to form an upper frequency output stereo signal.

6. The method according to claim 5, c h a r a c t e r i z e d i n that the remaining lower parts of the frequency range of the input audio stereo signal is processed differently so as to form a lower frequency output signal.

7. The method according to claim 6, c h a r a c t e r i z e d i n that said upper frequency stereo output signal is fed to a first audio reproduction system having two stereo loudspeaker units, whereas said lower frequency stereo output signal is fed to a second audio reproduction system.

8. The method according to claim 5, c h a r a c t e r i z e d i n that said second audio reproduction system includes only one loudspeaker unit.

9. An audio stereo signal reproduction system, comprising a pair of loudspeaker units (2', 2'') being acoustically isolated from each other, the units (2', 2'') sharing a common front surface (5) and having an effective sound propagation direction being essentially orthogonal to the front surface (5), the loudspeaker elements of said pair of loudspeaker

units (2', 2'') being identical to each other, c h a r a c t e r i z e d i n that

- each pair of loudspeaker units (2', 2'') is positionable as a unitary assembly in close proximity to each other,

- each loudspeaker element of each pair of corresponding, identical loudspeaker elements (3', 3'') of the two units (2', 2'') is mounted at essentially the same height

- the loudspeaker elements (3', 3'') of at least one of said pairs is mounted in immediate vicinity of each other.

10. An audio stereo signal reproduction system according to claim 9, c h a r a c t e r i z e d i n that each loudspeaker element of each pair of corresponding, identical loudspeaker elements (3', 3'') of the two units (2', 2'') is mounted in immediate vicinity of each other.

11. An audio stereo signal reproduction system according to claim 10, c h a r a c t e r i z e d i n that each loudspeaker element of each pair of corresponding, identical loudspeaker elements (3', 3'') in the two units (2', 2'') is mounted within a distance from each other of less than one quarter of the shortest wavelength emitted by the loudspeaker elements (3', 3'').

12. An audio stereo signal reproduction system according to claim 9, c h a r a c t e r i z e d i n that high frequency loudspeaker elements (3a) are horizontally positioned in line with mid frequency loudspeaker elements (3b).

13. An audio stereo signal reproduction system according to any one of claims 9 - 12, c h a r a c t e r i z e d i n that a plate element (4), is disposed centrally between said pair of loudspeaker units (2', 2''), from said front surface (5), in said effective sound propagation direction.

14. An audio stereo signal reproduction system according to any one of claims 9 - 13, c h a r a c t e r i z e d i n that said disc (4) projects from said front surface (5), in said effective sound propagation direction.

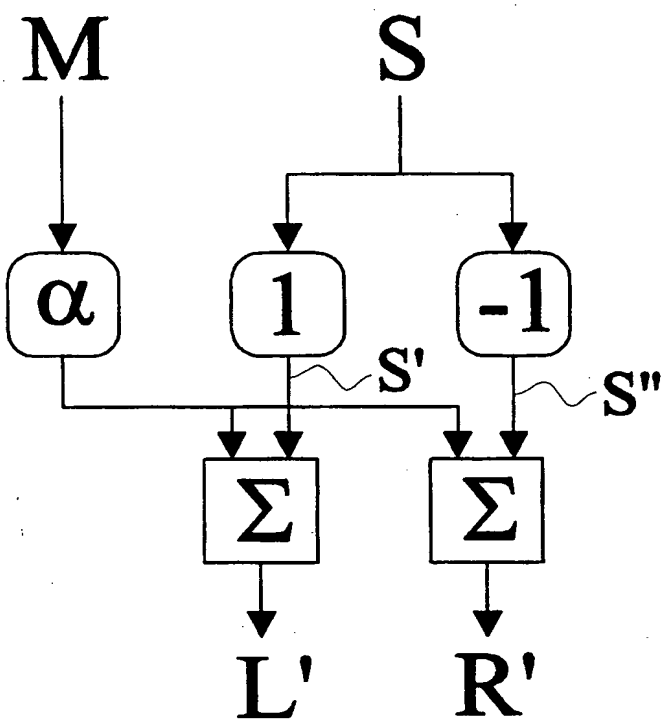

Fig. 1

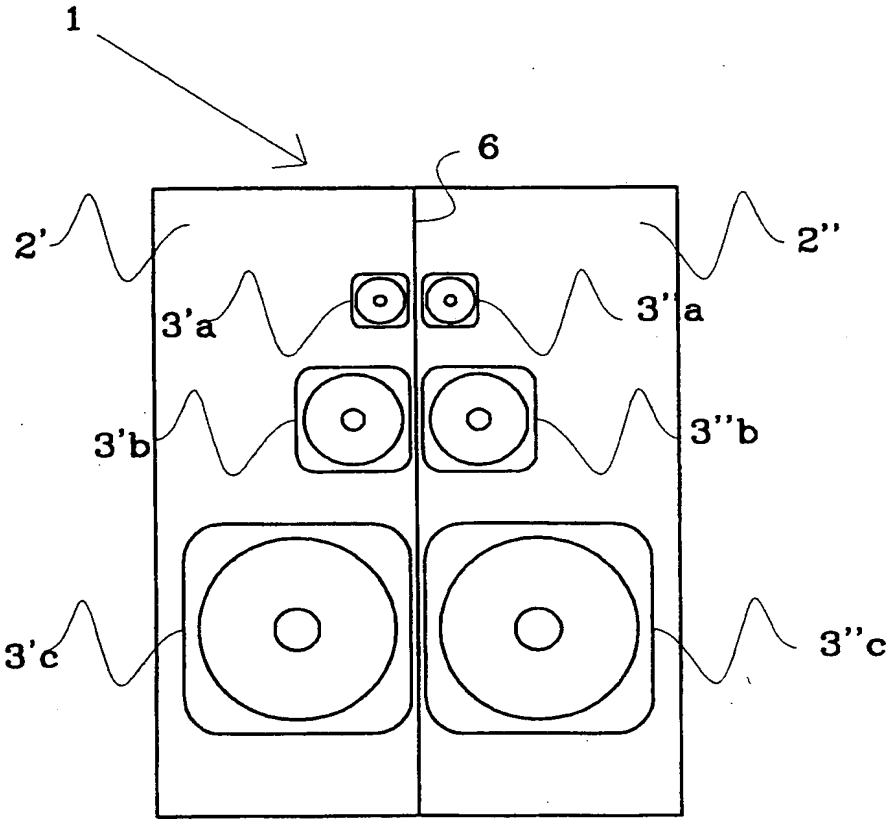

Fig. 2

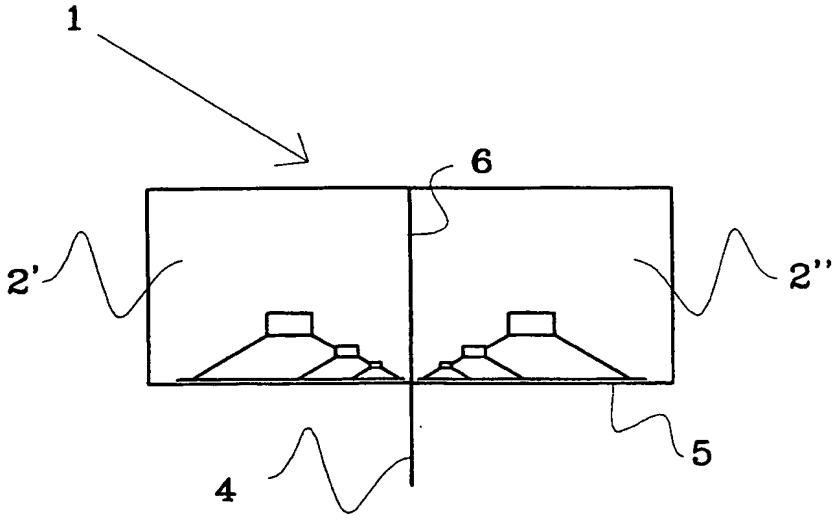

Fig. 3

INTERNATIONAL SEARCH REPORT

Information on patent family members

28/06/00

International application No.
PCT/SE 99/02193

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 3892624 A	01/07/75	NONE	
US 4596034 A	17/06/86	NONE	
WO 9730566 A1	21/08/97	EP 0880871 A	02/12/98
		GB 9603236 D	00/00/00
US 5579396 A	26/11/96	EP 0637191 A	01/02/95
		JP 2982627 B	29/11/99
		JP 8051698 A	20/02/96
		KR 137182 B	01/06/98
		JP 2947456 B	13/09/99
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		US 5761315 A	02/06/98
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		JP 11504478 T	20/04/99
		US 5661808 A	26/08/97
		WO 9634509 A	31/10/96
EP 773702 A2	14/05/97	NONE	

The phrase "...processed differently..." in claim 6 is not clear and concise about the processing for which protection is sought. Therefore, claim 6 violates PCT Article 6. Claims 7 and 8 refer to claim 6. Therefore, the violation of PCT Article 6 also extends over claims 7 and 8.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 99/02193

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☒ Claims Nos.: 6-8
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

.../...

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).:

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

One invention according to claims 1-8 referring to a method of processing and reproducing an input audio stereo signal, and one invention according to claims 9-14 referring to an audio stereo signal reproduction system.

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☒ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 99/02193

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 9730566 A1 (ADAPTIVE AUDIO LIMITED), 21 August 1997 (21.08.97), page 2, line 18 - line 24, fig. 1b (virtual sources vs. real sources), fig. 1a & 2 (closely spaced pair of loudspeakers)	8,9
A	--	1-5
X	US 5579396 A (T. IIDA ET AL), 26 November 1996 (26.11.96), figures 10,12,16,20, and accompanying text	8
A	--	1-5
A	US 5553147 A (J.E.M. PINEAU), 3 Sept 1996 (03.09.96), column 4, line 45 - column 5, line 15; column 7, line 33 - line 36, figures 3,4	1-5
A	--	
A	US 5892830 A (A.I. KLAYMAN), 6 April 1999 (06.04.99), abstract	1-5
A	--	
A	EP 773702 A2 (SRS LABS, INC.), 14 May 1997 (14.05.97), difference and summing circuits (11, 13)	1-5
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 99/02193

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: H04S 1/00
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: H04S

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3892624 A (S. SHIMADA), 1 July 1975 (01.07.75), column 1, line 40 - column 2, line 5; column 10, line 4 - line 29	8-11
A		1-5
	--	
X	US 4596034 A (J.P. MONCRIEFF), 17 June 1986 (17.06.86), figures 3c,4c,5c, and accompanying text	8-10,12-13
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[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" erlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
11 Sept. 2000	19 -09- 2000
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Leif Vingård / MRo Telephone No. +46 8 782 25 00

Form PCT/ISA/210 (second sheet) (July 1992)

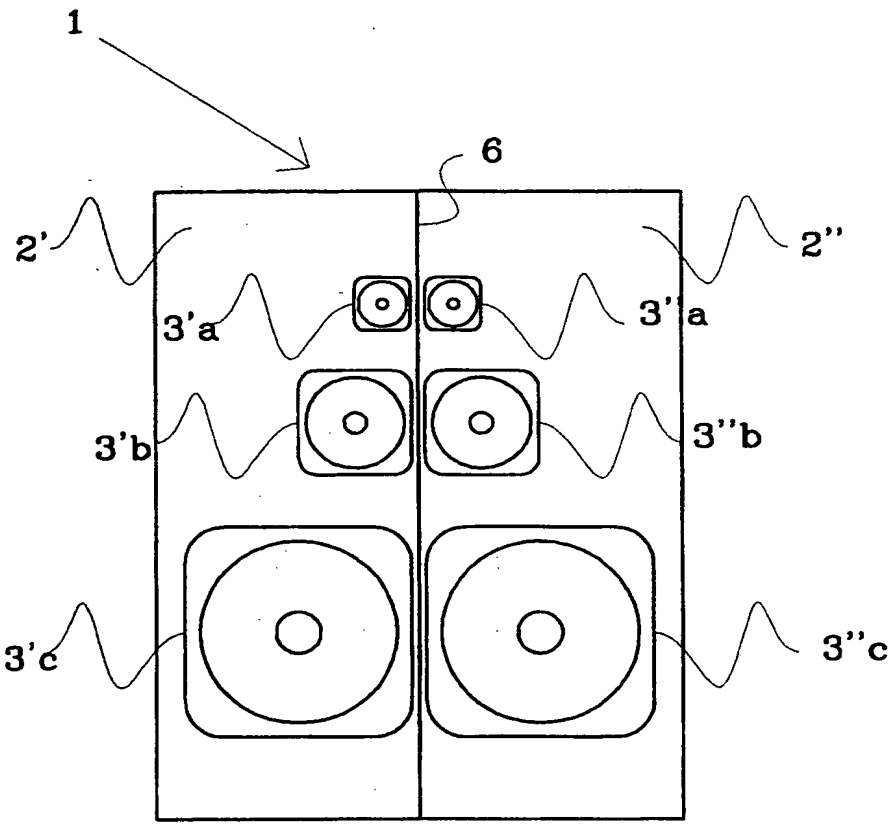

Fig. 2

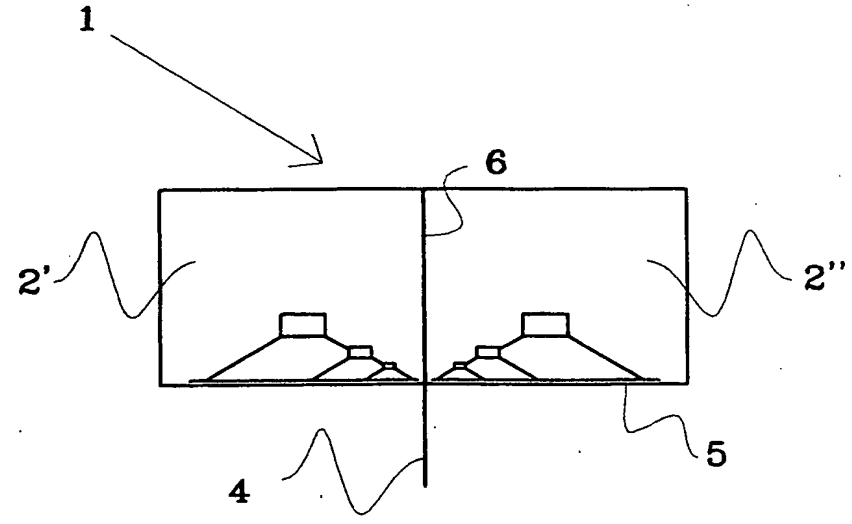

Fig. 3

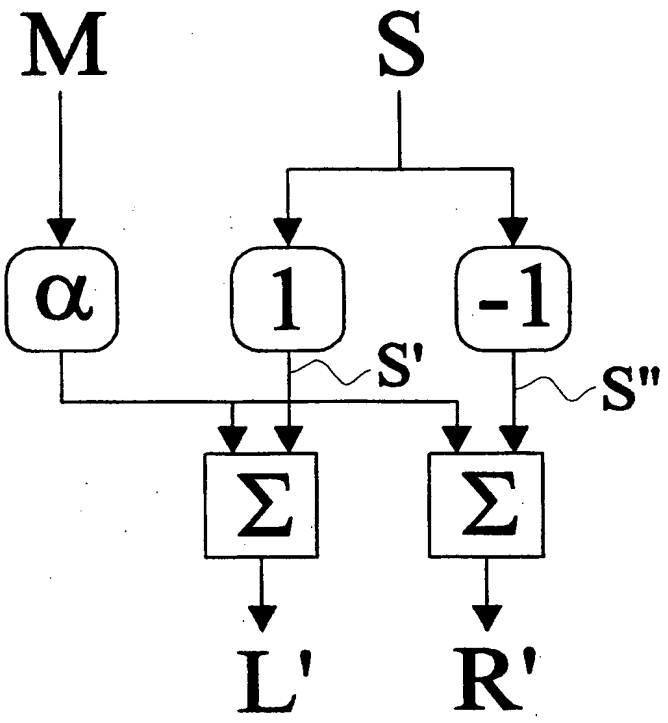

Fig. 1